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Feed intake and digestion in the summer and fall by different breeds of ewes consuming forages differing in quality

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Abstract

Sixteen penned, nonpregnant ewes (>3 years of age) of four breed groups (St. Croix, S; St. Croix×Texel, ST; Polypay×Texel, PT; Gulf Coast Native, N) were used in an experiment (west-central Arkansas; 2×4×2 factorial arrangement of treatments) to determine effects and interactions in feed intake and digestion of breed group, forage quality (mature bermudagrass, L; late-boot endophyte-free fescue, H), and season (summer, S; fall, F). Summer temperature humidity index [dry bulb temperature + (0.36×wet bulb temperature) +41.2°C] was considerably above and near 72 at 1600 and 0700 hours, respectively. Organic matter digestibility was similar between seasons for H but lower ($p<0.05$) in the summer vs. fall for L (46.1, 51.7, 61.9, and 62.3% for L–S, L–F, H–S, and H–F, respectively; SE 0.98). A comparable interaction between forage quality and season occurred in digestible OM intake (514, 607, 878, and 852 g day^{-1} for L–S, L–F, H–S, and H–F, respectively; SE 25.0). Digestible OM intake was similar among breed groups with L but greater ($p<0.05$) for ST and PT than for S and N with H (27.8, 30.3, 30.3, 26.5, 39.1, 49.5, 46.7, and 38.7 g kg^{-1} $BW^{0.75}$ for L–S, L–ST, L–PT, L–N, H–S, H–ST, H–PT, and H–N, respectively; SE 1.52). Digestible OM intake differed between low and high quality forages more in the summer than fall and varied among breed groups more with high vs. low quality forage; season did not alter the influence of forage quality on breed group differences.

Keywords: Sheep; Season; Forage quality; Feed intake; Digestion

1. Introduction

Interactions between animal biological type (i.e. genotype) and environment occur (Ferrell and Jenkins, 1985; Frisch and Vercoe, 1991; NRC, 1996). In general, species and breeds that have developed in a particular environment are well adapted for survival and (or) meat, milk, or fiber production depending on the degree and nature of human selection. Consequently, breeds from a specific environment may not perform similarly when placed in another setting. For example, breeds of ruminants vary in the ability to dissipate heat, which is primarily why *Bos indicus* cattle and hair sheep exhibit greater performance in tropical or subtropical environments than *Bos taurus* cattle or wool sheep, respectively.

Forages varying in quality or digestibility elicit absorption of different quantities of digestion end-products (e.g. acetate, propionate, amino acids; Minson, 1990). Quantities and arrays of absorbed

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digestion endproducts may influence the ratio of heat production to metabolized energy to impact feed intake (Ketelaars and Tolkamp, 1992; Tolkamp and Ketelaars, 1992). Similarly, animal characteristics, such as proportions of the whole body composed of protein and fat and metabolic activity per unit of tissue, influence heat production (Webster, 1981; Lobley, 1994), particularly through partitioning of acetate metabolism to heat production above basal metabolism (Leng, 1990; Cronjé et al., 1991; Tolkamp and Ketelaars, 1992; Leng et al., 1993; Scollan and Jessop, 1995). For example, Bhattacharya and Hussain (1974) noted the impact of dietary concentrate level on the depressing effect of heat stress on feed intake in sheep. In a related manner, Leng (1990) explained greater effects on forage intake of supplementation and relatively low intake of poor quality forage in tropical vs. temperate climates through diet effects on partitioning of acetate metabolism to heat generation vs. tissue accretion and impact of the environment on potential for heat dissipation. Therefore, it is conceivable that advantages or disadvantages of particular breeds or biological types of ruminants for high digestible OM intake might vary with the nature of ingested forage, season (i.e. temperature and humidity), and their interactions. In this regard, the objectives of this experiment were to investigate potential effects on, and interactions in, forage intake and digestion of different biological types of sheep, forage qualities, and climatic conditions or seasons.

2. Materials and methods

2.1. Animals

Sixteen nonpregnant ewes were used in an experiment with a 2×4×2 factorial arrangement of treatments, conducted at the USDA/ARS Dale Bumpers Small Farms Research Center in Booneville, AR, USA. Ewes were greater than 3 years of age, previously lambed at least twice, and were in moderate condition. Animals were cared for in accordance with guidelines of Consortium (1988). Ewes were of four breed groups (St. Croix, S; St. Croix×Texel, ST; Polypay×Texel, PT; Gulf Coast Native, N). St. Croix and N represent breeds known for adaption to hot and humid conditions that differ in mature weight and frame size. The ST and PT groups represent crossbreeds that differ in tolerance to heat and humidity, frame size, mature weight, and protein mass. Ewes were managed similarly on grass pasture before the experiment and between the two seasons. The ST, PT, and N ewes were sheared at the normal time, in late winter (i.e. February), and all ewes were dewormed at the beginning of each season. During the experiment, ewes resided in 1.2×1.2 m lambing pens in a wooden building with a metal roof and low-to-moderate ventilation.

2.2. Treatments

The experiment consisted of two crossovers, each with 21-day periods. One was in the hottest and most humid part of the year (summer season) and the second was in a cooler period (fall season). The summer crossover was from July 12 through August 22 1996, and the fall crossover was from October 25 through December 5 1996. Dietary treatments entailed ad libitum consumption of endophyte-free fescue [*Festuca arundinacea*; late-boot (high quality)] or mature bermudagrass hay [*Cynodon dactylon*; low quality (Table 1)]. Fescue was harvested in the spring of 1996 and bermudagrass immediately preceding the summer crossover. Hay was ground to pass a 1.9 cm screen.

Hay was fed once daily (0700 hours) at 105–110% of consumption on the preceding few days. Refused hay was removed and weighed preceding 0700 hours.

Table 1
Composition of forages consumed by ewes in the summer and fall seasons

Item	Summer		Fall	
	Low	High	Low	High
	% of dry matter			
Ash	7.2	10.1	7.2	11.4
CP	9.7	15.2	9.6	15.0
NDF	73.3	62.3	71.7	63.6
ADF	41.3	32.8	44.9	38.1
ADL	6.5	3.2	6.3	4.7
Cellulose	32.5	28.5	32.9	29.6
Hemicellulose	34.3	31.4	29.6	27.9

Low=mature bermudagrass; High=endophyte-free fescue (late-boot).

Approximately 4 g day^{-1} of a mixture of NaCl (42.9%), dicalcium phosphate (34.3%), trace mineral premix (14.3%; contained at least 12% Zn, 10% Fe, 8% Mn, 1.5% Cu, 0.3% I, 0.1% Co, and 0.02% Se; air-dry basis), and vitamin premix (8.6%; contained at least 8.8 million IU vitamin A, 1.8 million vitamin D_3, and 1100 IU vitamin E kg^{-1}; air-dry basis) were top-dressed on the hay.

2.3. Sampling and analyses

Hay composite samples were created by sampling on days 16–21. Fecal grab samples were obtained on the last 4 days of each period at 12 h intervals advancing 3 h daily. Feed intake was determined as the average of intake on the 2 days preceding and 4 days of fecal sampling. Rectal temperature was measured at 0700 and 1600 hours on day 21 of each period, and ewes were weighed at the end of each period. In addition, temperature and humidity in the barn near and at the same height as animals were measured at 0700 and 1600 hours daily. Temperature humidity index [THI; dry bulb temperature + (0.36×wet bulb temperature) +41.2°C] was calculated as described by Johnson (1987).

Hay samples were ground to pass a 1 mm screen. Fecal grab samples were dried at 55°C and ground to pass a 2 mm screen; composite fecal samples were then constructed (air-dry basis) and ground to pass a 1 mm screen. Feed and fecal samples were analyzed for DM (100°C), ash, Kjeldahl N (AOAC, 1984), NDF (filter bag technique; ANKOM Technology; Fairport, NY), and acid insoluble ash (2 N HCl; Van Keulen and Young, 1977). Hay samples also were analyzed for ADF and ADL (filter bag technique; ANKOM Technology), with cellulose determined as loss in weight upon sulfuric acid treatment and hemicellulose as the difference between NDF and ADF concentrations. Acid-insoluble ash was used as an internal, inert marker for estimating digestibility.

2.4. Statistical analyses

Data were analyzed by General Linear Models procedures of SAS (1990), as a crossover design with a block (breed) and as a split-plot (subplot of season; Milliken and Johnson, 1984). Sources of variation considered in the full model were: breed, sequence (order of forage treatments in the two periods of the seasons), breed×sequence×ewe (error for breed and sequence), forage, sequence×forage, breed×forage, breed×sequence×ewe×forage (error for forage, sequence×forage, and breed×forage), season, breed×season, forage×season, sequence×season, sequence×forage×season, breed×forage×season, breed×sequence×season, and breed×sequence×forage×season. Reduced models with omission of non-error term sources of variation involving sequence, tested with residual error, and having $p>0.10$ were then employed. The analysis of rectal temperature included the sub-subplot of time of measurement. Differences among means were determined by least significant difference procedures when the treatment F-test was significant ($p<0.07$).

3. Results

Low and high quality forages differed in composition as expected, with the concentration of CP lower and those of NDF and ADL greater for low vs. high quality forage (Table 1). Only small differences in composition were observed between seasons.

THI differed considerably between periods, although on the first few days of the seasons values were not greatly different (Fig. 1). Overall, other than the first segment of the fall season, THI did not change appreciably as experimental periods progressed in either season. In general, slightly greater differences between 0700 and 1600 hour values occurred in the summer than fall. Mean and 1600 hour THI values in the summer were generally greater than the critical value for dairy cattle production of 72 (Johnson, 1987). However, most 0700 hour summer values were near this point. No THI values in the fall indicate cold stress.

Body weight and $BW^{0.75}$ differed ($p<0.05$) with season (53.5 and 52.8 kg for summer and fall, respectively; SE 0.27), forage quality (52.6 and 53.7 kg for low and high quality forage, respectively; SE 0.32), and breed group (Table 2), although numerically, season and forage quality values were not markedly different and no interactions occurred. Breed groups ranked ($p<0.05$) S<ST<PT and N.

Season did not affect DM intake or interact with forage quality or season ($p>0.10$); however,

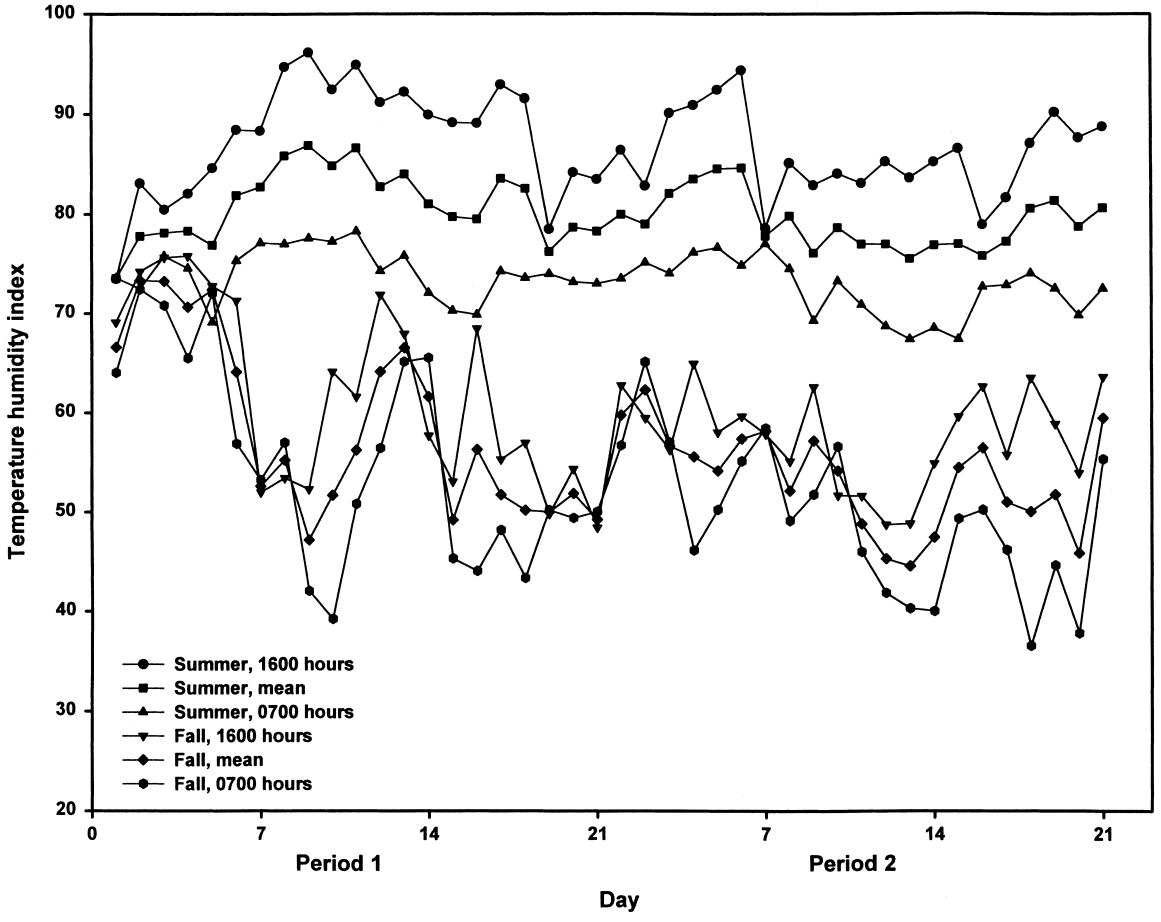

Fig. 1. THI (0700 and 1600 hours and mean) during the summer and fall.

interactions between forage quality and breed group occurred (p=0.05; Table 2). Differences among breed groups were much smaller for low than for high quality forage. Intake in g kg^{-1} $BW^{0.75}$ of high quality forage was less (p<0.05) for S and N than for ST and PT.

Apparent digestibilities of OM and NDF were affected by interactions between forage quality and season (p<0.03). Organic matter digestibility with high quality forage was similar in both seasons, but with low quality forage was greater (p<0.05) in the fall vs. summer (46.1, 51.7, 61.9, and 62.3% for summer – low quality forage, fall – low quality forage, summer – high quality forage, and fall – high quality forage, respectively; SE 0.98). Likewise, NDF digestibility differed more in the fall vs. summer, although the season difference was significant (p<0.05) for high as well as low quality forage (42.2, 48.7, 61.0, and 63.5% for summer – low quality forage, fall – low quality forage, summer – high quality forage, and fall – high quality forage, respectively; SE 0.84). Nitrogen digestibility was greater (p<0.05) for high rather than for low quality forage, but no interaction was noted between forage quality and season (Table 2).

Interactions (p<0.07) between forage quality and breed group and between forage quality and season occurred in digestible OM intake expressed in g day^{-1} and g kg^{-1} $BW^{0.75}$. Digestible OM intake was similar with high quality forage in both seasons, but greater (p<0.05) with low quality forage in the fall vs. summer (514, 607, 878, and 852 g day^{-1} for summer – low quality forage, fall – low quality forage, summer –

Table 2
Intake and digestibility for different breeds of ewes consuming low or high quality forage in summer and fall seasons

Item	Forage quality	Breed group				SE
		S	ST	PT	N	
BW						
kg	Mean	46.7[a]	51.7[b]	57.3[c]	57.0[c]	1.00
$kg^{0.75}$	Mean	17.8[a]	19.3[b]	20.8[c]	20.7[c]	0.29
DM intake						
g day^{-1}	Low	1085[a]	1274[b,c]	1362[c,d]	1213[a,b]	49.3
	High	1275[b,c]	1712[e]	1797[e]	1444[d]	
g day^{-1} kg^{-1} BW	Low	61.0[a,b]	67.0[b,c]	66.3[b,c]	58.8[a]	2.04
	High	71.4[c]	87.8[d]	85.2[d]	69.3[c]	
OM						
Intake (g day^{-1})	Low	1007[a]	1182[b,c,d]	1264[c,d]	1126[a,b]	44.1
	High	1139[b,c]	1528[e]	1604[e]	1289[d]	
Digestion (g day^{-1})	Low	494[a]	576[a,b]	623[b,c]	548[a,b]	33.7
	High	699[c]	966[e]	987[e]	807[d]	
g day^{-1} kg^{-1} $BW^{0.75}$	Low	27.8[a]	30.3[a]	30.3[a]	26.5[a]	1.52
	High	39.1[b]	49.5[c]	46.7[c]	38.7[b]	
NDF						
Intake (g day^{-1})	Mean	794[a]	1001[c]	1060[c]	894[b]	30.3
Digestion (g day^{-1})	Low	364[a]	409[a,b]	450[b,c]	398[a,b]	21.9
	High	494[cd]	686[e]	700[e]	562[d]	
N						
Intake (g day^{-1})	Low	16.7[a]	19.6[a,b]	21.0[b]	18.7[a,b]	1.19
	High	30.8[c]	41.3[e]	43.3[e]	34.8[d]	
Digestion (g day^{-1})	Low	9.7[a]	11.1[a]	11.9[a]	10.9[a]	0.96
	High	20.0[b]	27.6[d]	28.6[d]	23.2[c]	

Low=mature bermudagrass; High=endophyte-free fescue (late-boot); S=St. Croix; ST=St. Croix×Texel; PT=Polypay×Texel; N=Gulf Coast Native.
[a,b,c,d,e]Means within groupings of season, forage quality, or breed group without a common superscript differ ($p<0.05$).

high quality forage, and fall – high quality forage, respectively; SE 25.0). In g kg^{-1} $BW^{0.75}$, digestible OM intake was similar among breed groups with low quality forage but greater ($p<0.05$) for crossbreeds (i.e. ST and PT) than for purebreds (i.e. S and N) with high quality forage (26.2, 31.3, 44.1, 42.9 g day^{-1} for summer – low quality forage, fall – low quality forage, summer – high quality forage, and fall – high quality forage, respectively; SE 1.18).

An interaction ($p=0.02$) involving season, breed group, and time of measurement (i.e. 0700 and 1600 hours) in rectal temperature took place (Table 3). Summer rectal temperature ranked ($p<0.05$) S and N<ST and PT at 0700 hours; the ranking at 1600 hours was similar among breed groups except that rectal temperature for N did not differ from that for ST. Overall, differences among breed groups were of smaller magnitude in the fall, although the breed group ranking at 0700 hours was the same as that in the summer; the only breed group difference in the fall at 1600 hours was lower ($p<0.05$) rectal temperature for N vs. S, ST, and PT.

Table 3
Rectal temperature for different breeds of ewes consuming low or high quality forage in summer and fall seasons

Time (h)	Season	Breed group				SE
		S	ST	PT	N	
		°C				
0700	Summer	38.76[b]	39.10[c]	39.51[d]	38.87[b]	0.077
	Fall	38.45[a]	38.76[b]	38.83[b]	38.35[a]	
1600	Summer	39.10[c]	39.77[e]	40.07[f]	39.58[d,e]	
	Fall	38.68[b]	38.69[b]	38.74[b]	38.42[a]	

Low=mature bermudagrass; High=endophyte-free fescue (late-boot); S=St. Croix; ST=St. Croix×Texel; PT=Polypay×Texel; N=Gulf Coast Native.
[a,b,c,d,e,f]Means within groupings of season, forage quality, or breed group without a common superscript differ ($p<0.05$).

4. Discussion

4.1. THI

Summer THI values were typical of, or slightly greater than normal for, this region, which partially relates to housing in a building with a metal roof and low-to-moderate ventilation. Temperatures and humidities eliciting significant heat stress in sheep are not well established (Hernández Ledezma, 1987; Johnson, 1987; NRC, 1981, 1985). Nonetheless, because THI values of 72 or greater decrease productivity of dairy cattle, in part through decreased feed intake (Johnson, 1987), summer conditions might be expected to limit sheep productivity as well. Considerable differences in summer THI between 0700 and 1600 hours, with 0700 hours values near 72, indicate that heat stress varied appreciably within days and that the degree of heat stress was not marked for much of 24 h periods. Also, sheep used in the experiment had been reared at this location and, thus, were acclimated.

4.2. Digestibility

Effects of heat stress on digestibility vary with the nature of the diet and severity of heat stress (Bhattacharya and Hussain, 1974; Beede and Collier, 1986). Digestibility may increase if a decrease in feed intake slows the passage rate of digesta through the gut (NRC, 1981; Bunting et al., 1996). Conversely, digestibility can decrease, perhaps because increased water consumption shortens ruminal digesta residence time (Bhattacharya and Hussain, 1974; Bedö and Nikodémusz, 1996). Water consumption was not measured in the present experiment. However, by observation (i.e. frequency of filling water buckets) ewes consumed much more water in the summer than fall. Therefore, greater water consumption in the summer may have shortened the time during which digesta was exposed to ruminal microbial actions. Season×forage interactions in OM and NDF digestibilities were due to either an expected slower rate of ruminal digestion of low vs. high quality forage and thus, greater potential impact on digestion extent of ruminal residence time for low quality forage, or less of a difference in passage rate between seasons for high than for low quality forage.

4.3. Season×forage and season×breed

Digestible OM intake per kg $BW^{0.75}$ was similar between seasons for high quality forage, but for low quality forage was lower in the summer vs. fall. If whole body efficiency of energy metabolism was similar between seasons (Tolkamp and Ketelaars, 1994), this interaction may relate to additive effects of greater heat production from increased metabolic and respiration rates with summer heat stress and splanchnic bed metabolism, relative to absorbed energy (or DE intake), with low vs. high quality forage (Goetsch and Patil, 1997).

Season and breed group did not interact in digestible OM intake per kg $BW^{0.75}$. This could relate to nighttime conditions adequate for ample heat dissipation to avoid marked heat stress regardless of presumed greater heat tolerance of S and N vs. ST and PT and for ST vs. PT. In addition, these results suggest that degrees to which physiological changes to increase heat dissipation differed with season were similar among breed groups and within animal capabilities irrespective of breed group.

4.4. Forage×breed

Biological types of ruminants with high milk production or growth potential generally have greater maintenance energy requirements (ME required for energy stasis; fasting heat production plus heat increment) than those with lower potential (Ferrell and Jenkins, 1987; Frisch and Vercoe, 1991; NRC, 1996), which with constant whole body efficiency of energy metabolism indicates greater feed intake required for energy stasis. Also, it has been generalized that high production potential of some biological types is expressed only with nonstressful nutritional environments or high quality diets (Ferrell and Jenkins, 1985; Frisch and Vercoe, 1991; NRC, 1996). High quality diets elicit high peripheral tissue energy availability relative to absorbed energy, which with high capacity for peripheral tissue energy accretion or secretion in milk apparently allows a level of feed intake more than compensatory for high maintenance energy demand. High splanchnic bed energy use relative to DE intake with low quality diets corresponds to a low quantity of energy used by extra-splanchnic tissues, and with high production potential a high proportion of this energy is

devoted to maintenance. Thus, digestible OM intake per kg $BW^{0.75}$ with very low quality forage-based diets would be greater for biological types with low vs. high production potential, and as forage quality increases feed intake and energy accretion or secretion in milk should change more for biological types with high potential.

In accordance with aforementioned rationale, greater potential for digestible OM intake per kg $BW^{0.75}$ of crossbreed groups than for purebreds was expressed with high quality forage, although the expectation for greater purebred intake of low quality forage was not realized. A higher ratio of splanchnic bed heat production to DE intake for low vs. high quality forage would be associated with a lower absolute quantity and proportion of absorbed energy metabolized by, and heat increment associated with, peripheral tissues. This may have limited potential for expression in intake of low quality forage of any differences among breed groups in peripheral tissue basal metabolism or fasting heat production, heat increment, or potential energy accretion or partitioning of acetate metabolism.

5. Conclusions

In summary, heat stress of summer months in west-central Arkansas elicited a slight decrease in digestibility of a pen-fed mature tropical grass hay regardless of ewe breed group (St. Croix, St. Croix×Texel, Polypay×Texel, Gulf Coast Native). Digestible OM intake was similar between seasons with a higher quality temperate grass hay, but with bermudagrass hay was less in the summer vs. fall. Crossbreed ewes consumed more digestible OM relative to $BW^{0.75}$ with the temperate grass than did the purebreds regardless of season; whereas digestible OM intake per kg $BW^{0.75}$ was similar among breed groups with the tropical grass.

In conclusion, although exact physiological conditions responsible for the aforementioned interactions are unclear, these results suggest that magnitudes of difference in digestible OM intake among forages may be greater in hot vs. cool seasons, and higher quality forages can yield greater differences among biological types in digestible OM intake than forages lower in quality. Differences in heat stress tolerance of penned, nonpregnant ewes of these breed groups did not appear to influence digestible OM intake. No findings indicated season effects on differences among breed groups in digestible OM intake with the different quality forages.

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